Web Appendix for Secrecy and Safety

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Proof of Claim 1 from the Appendix. We provide only the proof of part (a) below; the complete proof of part (b) can be obtained by adapting the arguments from Reinganum and Wilde (1986), which uses iterated D1 (Universal Divinity; see Banks and Sobel, 1987, and Cho and Kreps, 1987) since only one iteration is required. However, we note here a few critical attributes of the uniqueness proof. In a revealing equilibrium, the function $s(p_2; \Theta)$ must be decreasing (if higher prices also result in no fewer sales, they will be mimicked) and continuous from the left on the equilibrium price interval (a jump, which must be downward, would induce a defection to a lower price by types whose (higher) equilibrium prices lie in a neighborhood of the price at which the jump occurs). The same argument implies that $s(p_2; \Theta) = 1$ when p_2 is the lowest equilibrium price. A jump can occur after the highest equilibrium price, since there are no types with a higher equilibrium price that might be tempted to defect downward. Finally, since $s(p_2; \Theta)$ is decreasing and continuous on the equilibrium price interval, it is differentiable almost everywhere, and therefore must satisfy the differential equation provided in the text. Solving this equation through the specified boundary condition provides a unique candidate for a revealing equilibrium. The remainder of the proof verifies that this is a revealing equilibrium when $\beta > L_D^C$.

First, we note that, given the beliefs specified in (i), the consumer is indifferent between buying and not buying at any price $p_2 \in [V - (1 - \Theta)L_P^C, V - (1 - \bar{\theta})L_P^C]$. This is because if she buys at price p_2, she expects surplus of $V - p_2 - [1 - (1 - (V - p_2)/L_P^C]L_P^C = 0$. Thus it is optimal for the consumer to randomize as specified in (ii). Any price $p_2 > V - (1 - \bar{\theta})L_P^C$ will yield negative surplus, regardless of the consumer's inferred value of $\theta_1 \in [\Theta, \bar{\theta}]$, so it is optimal to buy with probability zero. Finally, any price $p_2 < V - (1 - \Theta)L_P^C$ will yield positive surplus, regardless of the consumer's inferred value of $\theta_1 \in [\Theta, \bar{\theta}]$, so it is optimal to buy with probability one. Thus, given the consumer's beliefs as in (i), the probability of sale function given in (ii) is optimal.

Given the probability of sale function in (ii), the firm with retained technology of type θ_1 receives profits of $\Pi_2^C(r; \theta_1, \Theta) = \max_{p_2} Ns(p_2; \Theta)[p_2 - (1 - \theta_1)L_D^C] + N[1 - s(p_2; \Theta)]\beta\theta_1$. First note that any price $p_2 < V - (1 - \Theta)L_P^C$ is dominated by the price $p_2 = V - (1 - \Theta)L_P^C$ since both result in a sure sale. Any price $p_2 > V - (1 - \bar{\theta})L_P^C$ is dominated by $p_2 = V - (1 - \bar{\theta})L_P^C$ since the former price results in no sale and the latter results in a positive probability of sale at a profitable price. Differentiating with respect to p_2 and collecting terms implies that $s' = -\alpha s/B < 0$ and $s'' = \alpha(\alpha + 1)s/B^2 > 0$. The first-order condition $s'[p_2 - (1 - \theta_1)L_D^C - \beta\theta_1] + s = 0$ has the unique solution $p_2 = p_2^*(\theta_1) = V - (1 - \theta_1)L_P^C$. To see that this provides a maximum, we evaluate the second-order condition:

$$s''[p_2 - (1 - \theta_1)L_D^C - \beta\theta_1] + 2s' = [\alpha(\alpha + 1)s/B^2][p_2 - (1 - \theta_1)L_D^C - \beta\theta_1] - 2\alpha s/B$$

$$= [\alpha s/B^2][(1 + \alpha)(p_2 - (1 - \theta_1)L_D^C - \beta\theta_1) - 2B]$$

at $p_2 = p_2^*(\theta_1) = V - (1 - \theta_1)L_P^C$. Upon making this substitution, the term $[(1 + \alpha)(p_2 - (1 - \theta_1)L_D^C - \beta\theta_1) - 2B]$ reduces to $[(L_D^C - \beta)/(L^C - \beta)][V - (1 - \theta_1)L^C - \beta\theta_1] < 0$. Thus, the function $p_2^*(\theta_1) = V - (1 -$

$\theta_1)L_P^C$ provides the unique interior maximum. Moreover, if there were another maximum at either end of the interval $[V - (1 - \Theta)L_P^C, V - (1 - \bar{\theta})L_P^C]$, then there would have to be an interior minimum between $p_2^*(\theta_1) = V - (1 - \theta_1)L_P^C$ and that endpoint. Since $p_2^*(\theta_1) = V - (1 - \theta_1)L_P^C$ is the unique solution to the first-order condition, there can be no interior minimum. Hence, $p_2^*(\theta_1) = V - (1 - \theta_1)L_P^C$ is the optimal price, given $s(p_2; \Theta)$.

Since the resulting payoff $\Pi_2^C(r;\ \theta_1,\ \Theta) = Ns(p_2^*(\theta_1);\ \Theta)[p_2^*(\theta_1) - (1 - \theta_1)L_D^C] + N[1 - s(p_2^*(\theta_1); \Theta)]\beta\theta_1$ is an increasing function of θ_1, the retention interval will be of the form $[\Theta, \bar{\theta}]$, with the worst retained technology satisfying $\Pi_2^C(r; \theta, \theta) = \Pi_2^C(n)$; that is, $\Pi_2^C(r; \theta, \theta) = N[V - (1 - \theta)L^C] = N[V - (1 - \mu)L^C] - t$. Solving for the worst technology retained yields $\theta^C = \mu - t/NL^C$.

It is clear that firms with technologies of types $\theta_1 > \theta^C$ are better off retaining them. It remains to verify that a firm of type $\theta_1 < \theta^C$ would not want to deviate from replacing the technology to retaining it and charging some price $p_2 \in [V - (1 - \theta^C)L_P^C, V - (1 - \bar{\theta})L_P^C]$. The best price for a firm of type $\theta_1 < \theta^C$ is $p_2 = V - (1 - \theta^C)L_P^C$, which yields a sure sale (and lower quality firms value a sale more than higher quality firms). But then the firm's profit is $N[V - (1 - \theta^C)L_P^C - (1 - \theta_1)L_D^C] < N[V - (1 - \theta^C)L_P^C - (1 - \theta^C)L_D^C] = N[V - (1 - \mu)L^C] - t$. Thus, a firm of type $\theta_1 < \theta^C$ prefers to replace the technology. Finally, it is straightforward to verify that the consumer's beliefs are correct in equilibrium. QED.

<u>Proof of Proposition 1</u>. Write $s^*(\theta_1; \theta^C) = \{A/B\}^\alpha$, where $A = V - (1 - \theta^C)L^C - \beta\theta^C$, $B = V - (1 - \theta_1)L^C - \beta\theta_1$, and $\alpha = L_P^C/(L^C - \beta)$. Note that $A > 0$, $B > 0$ and $B > A$ for $\theta_1 > \theta^C$. Then $s^{*\prime}(\theta_1; \theta^C) = -\alpha s^*(L^C - \beta)/B < 0$ and $s^{*\prime\prime}(\theta_1; \theta^C) = \alpha(1 + \alpha)s^*[(L^C - \beta)/B]^2 > 0$. The parameters V and β enter directly, and do not affect θ^C. Differentiation yields:

$$\partial s^*(\theta_1; \theta^C)/\partial V = \alpha s^*(L^C - \beta)(\theta_1 - \theta^C)/AB > 0 \text{ for all } \theta_1 \in (\theta^C, \bar{\theta}] \text{ (and } = 0 \text{ for } \theta_1 = \theta^C).$$
$$\partial s^*(\theta_1; \theta^C)/\partial\beta = \alpha s^*[\ln\{A/B\}/(L^C - \beta) + (V - L^C)(\theta_1 - \theta^C)/AB].$$

Let $\gamma(\theta_1) \equiv \ln\{A/B\}/(L^C - \beta) + (V - L^C)(\theta_1 - \theta^C)/AB$. Since $\gamma(\theta^C) = 0$ and $\gamma'(\theta_1) = -(L^C - \beta)\theta_1/B^2 < 0$, it follows that $\gamma(\theta_1) < 0$ for all $\theta_1 \in (\theta^C, \bar{\theta}]$. Thus, $\partial s^*(\theta_1; \theta^C)/\partial\beta < 0$ for all $\theta_1 \in (\theta^C, \bar{\theta}]$ (and $= 0$ for $\theta_1 = \theta^C$). The parameters N, t and μ enter only indirectly through θ^C. Since $\partial s^*(\theta_1; \theta^C)/\partial\theta^C = \alpha s^*(L^C - \beta)/A > 0$, it follows that $\text{sgn}\{\partial s^*(\theta_1; \theta^C)/\partial\rho\} = \text{sgn}\{\partial\theta^C/\partial\rho\}$ for $\rho = N$, t or μ. Since $\theta^C = \mu - t/NL^C$, we have $\partial s^*(\theta_1; \theta^C)/\partial N > 0$; $\partial s^*(\theta_1; \theta^C)/\partial\mu > 0$; and $\partial s^*(\theta_1; \theta^C)/\partial t < 0$. QED.

<u>Partial Derivatives of H(V, t/N)</u>.

Recall that $H(V, t/N) \equiv \int^C[\theta s^*(\theta; \theta^C) - \mu]g(\theta)d\theta$, where $\theta^C = \mu - t/NL^C$. In the text, we claimed that (a) $\partial H/\partial V > 0$; and (b) $\partial H/\partial(t/N) < 0$.

<u>Proof of (a)</u>. $\partial H/\partial V = \int^C\theta_1(\partial s^*(\theta_1; \theta^C)/\partial V)g(\theta_1)d\theta_1$. Recall that $\partial s^*(\theta_1; \theta^C)/\partial V > 0$ for all $\theta_1 \in (\theta^C, \bar{\theta}]$, and $\partial s^*(\theta_1; \theta^C)/\partial V = 0$ for $\theta_1 = \theta^C$ (see Proposition 1). Since θ^C itself is independent of V, it is clear that $\partial H/\partial V > 0$.

<u>Proof of (b)</u>. $\partial H/\partial(t/N) = (\theta^C - \mu)g(\theta^C)/L^C + \int^C\{\theta_1[\partial s^*(\theta_1; \theta^C)/\partial(t/N)]\}g(\theta_1)d\,\theta_1$. The first term is negative since $\theta^C < \mu$. The second term is negative since $\partial s^*(\theta_1; \theta^C)/\partial(t/N) < 0$ for all $\theta_1 \in [\theta^C, \bar{\theta}]$ (see Proposition 1). Thus, $\partial H/\partial(t/N) < 0$. QED.

To ascertain parameter combinations (in terms of V and t/N) under which this is likely to occur, we first note that $E(\sigma; \theta^C) < N\mu$ if and only if $\int^C N[\theta_1 s^*(\theta_1; \theta^C) - \mu]g(\theta_1)d\theta_1 < 0$. Let:

$$H(V, t/N) \equiv \int^C [\theta_1 s^*(\theta_1; \theta^C) - \mu]g(\theta_1)d\theta_1.$$

Some Examples Illustrating Declining versus Improving Intertemporal Safety Provision

The average safety of products sold is the same in both periods when H(V, t/N) = 0. Suppose we begin at a parameter pair (V, t/N) at which H(V, t/N) = 0. Then, since it can be shown (see the Web Appendix) that $\partial H/\partial V > 0$ and $\partial H/\partial(t/N) < 0$, it follows that the average safety of products sold is more likely to decline from Period 1 to Period 2 when V is low, or when t/N is high. In particular, this means that H(V, t/N) = 0 yields an increasing function when graphed in (V, t/N) space. It is difficult to explore H in more detail analytically, so we use some examples to illustrate this surface between declining and improving intertemporal safety provision. We now fix the region of analysis and the parameter values. Since $0 \leq \theta^C \leq \mu$, this means that $0 \leq t/NL^C \leq \mu$. Further, from Assumption 1, we require $V/L^C > 1$; this is also the economically relevant region, since otherwise the product potentially generates higher social costs than value. In the computations below: 1) $1 < V/L^C \leq 3$; 2) $L_P^C/L^C = 0.5$; and 3) $[\underline{\theta}, \bar{\theta}] = [0, 1]$. Note that $L_P^C/L^C = 0.5$ and $\beta > L_D^C$ implies that $\beta/L^C > 0.5$; we have chosen to use $\beta/L^C = 0.6$. Runs with higher values of β/L^C gave very similar results. The calculations were performed using *Mathematica 4.2*.

Diagrams for H = 0 When the Distribution is Symmetric

Figure A1 below illustrates these computations, for selected members of the family of Beta distributions (see Johnson and Kotz, 1970, Chapter 24); that is $G(\theta) = \text{Beta}(\theta; p, q)$, where we have chosen to use the parameter values (p,q) to be (1,1), (2,2), and (3,3). These (p,q) values provide symmetric distributions, all with mean equal to ½, and with increasing "peakedness," as illustrated in the left panel of Figure A1 below.

In the figure the density functions are on the left, while (for each G) the boundary between declining and improving intertemporal safety of the product sold is displayed on the right. For example, the case (p,q) = (1,1) is the uniform density, illustrated on the left of the figure. The curve on the right labeled (1,1), is the resulting H = 0 locus, which implicitly defines levels of t/NL^C, as a function of V/L^C, that induce Period 2 average safety of products sold exactly equal to the average safety of products sold in Period 1. Points above this curve are associated (under the uniform distribution) with declining intertemporal safety, while points below this curve are associated (under the uniform distribution) with increasing intertemporal safety. Thus, starting at a point on the curve, an increase in t results in a higher cost of R&D, a lower threshold θ^C and a lower value of $s^*(\theta_1; \theta^C)$ at any $\theta_1 > \theta^C$ (see Lemma 1 in the main text). Such an increase results in sufficient demand reduction to make the average safety of products sold in Period 2 lower than that of Period 1. A reverse effect would occur if we had increased V instead. This same discussion applies for the other densities illustrated.

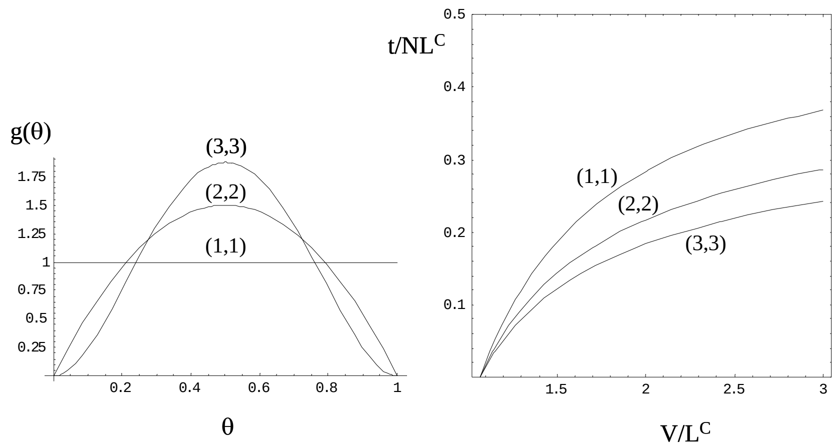

Figure A1: The Effect of Mean-Preserving Spreads on the Change in the Equilibrium Average Safety of Products Sold Under Confidentiality (Symmetric Distribution Case)

Figure A1 also suggests that a distribution $\tilde{G}$ which is a mean-preserving spread of G (as, for example, the distribution represented by (p,q) = (1,1) yields a mean-preserving spread of the distribution represented by (p,q) = (2,2)) will result in an associated curve in (V/L^C,t/NL^C) space which is everywhere higher than that curve associated with G. Unfortunately, we have not been successful in characterizing when (or under what conditions on G) mean-preserving spreads provide the dominance suggested by the right-hand-side panel of Figure A1. However, this property is intuitively reasonable. A mean-preserving spread $\tilde{G}$ of G places more weight on high types and on low types than G does. Now consider a specific level of t/NL^C (equivalently, fix a value of θ^C). While a larger proportion of types under $\tilde{G}$ is rejected due to θ^C than is rejected under G, more high types are left, too. Thus, for a given level of t/NL^C, H should be larger under $\tilde{G}$ than under G for higher values of V. This is the pattern observed above.

<u>Diagrams for H = 0 When the Distribution is Not Symmetric</u>

In what follows we use the same parameter values as employed above, except for the (p,q) pairs associated with the beta distribution. Figure A2 displays results for three mean-preserving left-skewed distributions (μ = 1/3), while Figure A3 displays results for three mean-preserving right-skewed distributions (μ = 2/3). Note that the diagrams on the right of Figures A2 and A3 are for the space $[1, 3]\times[0, \mu]$ and that μ for Figure A2 is 1/3 while μ for Figure A3 is 2/3.

<u>Proof that $M'(\lambda^O) < 0$ and $M''(\lambda^O) > 0$.</u>

Notice that: $M'(\lambda^O) = d\Pi_1^O(\lambda^O)/d\lambda^O$

$$= N[-(1-\mu)K_S](1+G(\theta^O)) + \{N[V-(1-\mu)L^O] - t\}g(\theta^O)(d\theta^O/d\lambda^O)$$
$$- N[V-(1-\theta^O)L^O]g(\theta^O)(d\theta^O/d\lambda^O) + \int^{O} N[-(1-\theta_1)K_S]g(\theta_1)d\theta_1.$$

The first and fourth terms above are both negative. The two middle terms correspond to $\Pi_2^O(n) - \Pi_2^O(r;\theta^O)$, which cancel each other out by the definition of the retention threshold θ^O. Thus, $M'(\lambda^O) < 0$. Moreover, differentiating again yields $M''(\lambda^O) = NK_S g(\theta^O)(d\theta^O/d\lambda^O)[\mu - \theta^O]$. Since $d\theta^O/d\lambda^O > 0$ and $\mu > \theta^O$, then $M''(\lambda^O) > 0$. QED.

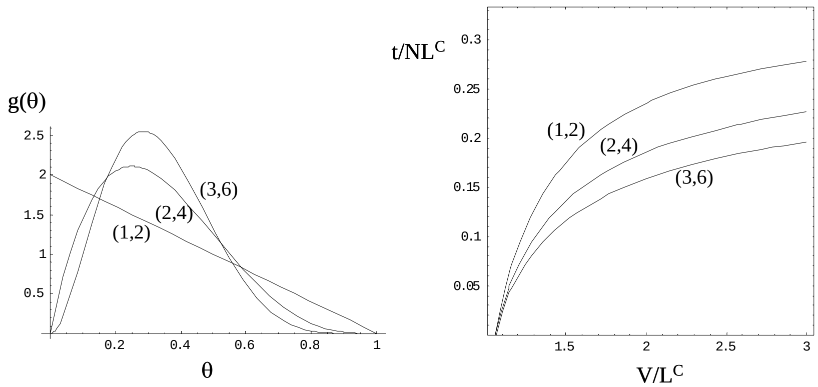

Figure A2: The Effect of Mean-Preserving Spreads on the Change in the Equilibrium Average Safety of Products Sold Under Confidentiality (Left-Skewed Distribution Case)

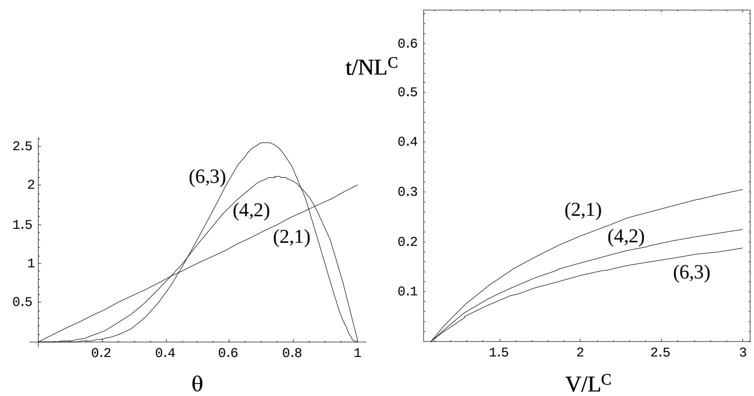

Figure A3: The Effect of Mean-Preserving Spreads on the Change in the Equilibrium Average Safety of Products Sold Under Confidentiality (Right-Skewed Distribution Case)

<u>Details of the Impact of Third Party Harms on $M(\lambda^O; \phi)$</u>.

$$M(\lambda^O; \phi) = \Pi_1^O(\lambda^O; \phi) - \Pi_1^O(\lambda^C; \phi) + \int^C N[1 - s^*(\theta_1; \theta^C)][V - (1 - \theta_1)\tilde{L}^C - \beta\theta_1]g(\theta_1)d\theta_1.$$

Notice that (upon recalling that $1 - s^*(\theta^C; \theta^C) = 0$):

$$\partial M(\lambda^O; \phi)/\partial\phi = \partial\Pi_1^O(\lambda^O; \phi)/\partial\phi - \partial\Pi_1^O(\lambda^C; \phi)/\partial\phi$$

$$+ \int^C N\{[-\partial s^*(\theta_1; \theta^C)/\partial\phi][V - (1 - \theta_1)\tilde{L}^C - \beta\theta_1] + [1 - s^*(\theta_1; \theta^C)][-(1 - \theta_1)L_D^C\}g(\theta_1)d\theta_1.$$

The first two terms cancel out when $\lambda^O = \lambda^C$, and the integrand will surely be negative if $\partial s^*(\theta_1; \theta^C)/\partial\phi \geq 0$. A sufficient condition for $\partial s^*(\theta_1; \theta^C)/\partial\phi \geq 0$ for all $\theta_1 \in [\theta^C, \bar{\theta}]$ is:

$$-(V - \tilde{L}^C)\ln\{(V - \tilde{L}^C)/(V - \beta)\} - (\tilde{L}^C - \beta) + (t/N)((\tilde{L}^C - \beta)/\tilde{L}^C)^2 \geq 0. \quad (*)$$

To see this, notice that the function $s^*(\theta_1; \theta^C)$ depends on ϕ only through $\tilde{L}^C$; thus $\partial s^*(\theta_1; \theta^C)/\partial\phi = (\partial s^*(\theta_1; \theta^C)/\partial\tilde{L}^C)(\partial\tilde{L}^C/\partial\phi)$. Since $\partial\tilde{L}^C/\partial\phi > 0$, we need only find a sufficient condition for $\partial s^*(\theta_1; \theta^C)/\partial\tilde{L}^C \geq 0$ for all $\theta_1 \in [\theta^C, \bar{\theta}]$. Differentiating $s^*(\theta_1; \theta^C)$ with respect to $\tilde{L}^C$ yields:

$$\partial s^*(\theta_1; \theta^C)/\partial\tilde{L}^C = [\alpha s^*/A(\tilde{L}^C - \beta)]\{ -A\ln\{A/B\} + (V - \beta)(A - B)/B + (t/N)((\tilde{L}^C - \beta)/\tilde{L}^C)^2\},$$

where $A \equiv V - (1 - \theta^C)\tilde{L}^C - \beta\theta^C$ and $B \equiv V - (1 - \theta_1)\tilde{L}^C - \beta\theta_1$. Let $\eta(\theta_1) \equiv -A\ln\{A/B\} + (V - \beta)(A - B)/B + (t/N)((\tilde{L}^C - \beta)/\tilde{L}^C)^2$. Then $\eta(\theta^C) = (t/N)((\tilde{L}^C - \beta)/\tilde{L}^C)^2 > 0$ and $\eta'(\theta_1) = -A(\tilde{L}^C - \beta)^2(1 - \theta_1)/B^2 < 0$. Thus, a sufficient condition for $\partial s^*(\theta_1; \theta^C)/\partial\tilde{L}^C \geq 0$ for all $\theta_1 \in [\theta^C, \bar{\theta}]$ is that $\eta(\bar{\theta}) \geq 0$. The worst-case scenario is provided by $\bar{\theta} = 1$.

Upon substituting $\theta^C = \mu - t/N\tilde{L}^C$, we can see that $\eta(1; \mu) = -[V - (1 - \mu + t/N\tilde{L}^C)\tilde{L}^C - \beta(\mu - t/N\tilde{L}^C)]\ln\{[V - (1 - \mu + t/N\tilde{L}^C)\tilde{L}^C - \beta(\mu - t/N\tilde{L}^C)/(V - \beta)\} - (1 - \mu + t/N\tilde{L}^C)(\tilde{L}^C - \beta) + (t/N)((\tilde{L}^C - \beta)/\tilde{L}^C)^2$. If we wanted to guarantee that $\eta(1; \mu) \geq 0$ <u>for all</u> μ, we would want it to be non-negative in the worst-case scenario. Since $\partial\eta(1; \mu)\partial\mu = -(\tilde{L}^C - \beta)\ln\{[V - (1 - \mu + t/N\tilde{L}^C)\tilde{L}^C - \beta(\mu + t/N\tilde{L}^C)]/(V - \beta)\} > 0$, the worst-case scenario occurs when μ is as small as possible. In order to keep θ^C non-negative, this means that the lowest possible value of μ is $\mu = t/N\tilde{L}^C$. Evaluating $\eta(1; \mu)$ at $\mu = t/N\tilde{L}^C$ yields: $\eta(1; t/N\tilde{L}^C) = -(V - \tilde{L}^C)\ln\{(V - \tilde{L}^C)/(V - \beta)\} - (\tilde{L}^C - \beta) + (t/N)((\tilde{L}^C - \beta)/\tilde{L}^C)^2 \geq 0$ under the displayed condition (*). Thus, this condition ensures that $\eta(1; \mu) \geq 0$ for all $\mu \in [t/N\tilde{L}^C, 1]$, which implies $\partial s^*(\theta_1; \theta^C)/\partial\tilde{L}^C \geq 0$ (and thus $\partial s^*(\theta_1; \theta^C)/\partial\phi \geq 0$) for all $\theta_1 \in [\theta^C, \bar{\theta}]$. QED.

<u>Detailed Analysis of the Confidential Regime when $\beta < L_D^C$</u>

We have shown that a revealing equilibrium exists when $\beta > L_D^C$. In a revealing equilibrium, a firm with a safer product must demand a higher price (and must suffer more demand-reduction). Thus, a revealing equilibrium can only exist if a firm with a safer product is willing to absorb a reduction in volume in exchange for a higher price. Recalling the firm's profit function (equation (4)), we see that the type that will be most willing to suffer a given reduction in demand is the type for which $p_2 - (1 - \theta_1)L_D^C - \beta\theta_1$ is the smallest (since this represents the foregone profit, net of the opportunity cost, from selling one fewer units of the product). Since this expression is decreasing in θ_1 when $\beta > L_D^C$, the safest type suffers the least from demand reduction. Consequently, firms with safer products are willing to suffer more demand reduction in return for higher prices. However, when $\beta < L_D^C$, the firm with the safest product suffers the <u>most</u> from demand reduction. In this case, there cannot be a perfect Bayesian equilibrium involving revelation; any perfect Bayesian equilibrium involves complete pooling; the following proof is of Claim 2 (see the Appendix for the paper).

<u>Proof of Claim 2</u>. It is straightforward to verify that the strategies and beliefs provided constitute a pooling equilibrium. Technically, any price $p_2 \in [V - (1 - \theta^{CP})L_P^C, V - (1 - \mu(\theta^{CP}))L_P^C]$ can be supported as a PBE since upward deviations are inferred to come from type θ^{CP}, and are therefore rejected. However, the PBE specified in Claim 2 is the natural analog of that characterized in Section 3. The more interesting part of this claim is that there can be no revelation in equilibrium. To see why, suppose there is partial revelation. This could take one of the following forms: (a) an

interval of types who reveal according to the price function $p(\theta_1) = V - (1 - \theta_1)L^C_P$; or (b) an interval of types $[\theta^-, \theta^+]$ partitioned by a marginal type θ^m, so that the types $[\theta^-, \theta^m)$ prefer the price p^-_2, the types $(\theta^m, \theta^+]$ prefer the price $p^+_2 > p^-_2$ and type θ^m is indifferent between these two prices. We argue that neither of these can be part of an equilibrium.

(a) As argued above in the proof of Claim 1, if an interval of types reveals according to the price function $p(\theta_1) = V - (1 - \theta_1)L^C_P$, then these types face a decreasing and continuous probability of sale function $s(p_2)$ which must satisfy the differential equation (6) from the text. The solution to this equation is of the form $s(p_2) = \{\Delta/[p_2(L^C - \beta) + \beta V - \beta L^C_P - VL^C_D]\}^\alpha$, where $\alpha \equiv L^C_P/(L^C - \beta)$. (The constant of integration Δ need not be evaluated here, as we will show that a contradiction arises regardless of this value). Checking the second-order condition, evaluated at $p(\theta_1) = V - (1 - \theta_1)L^C_P$ (see the proof of Claim 1), implies that this price now provides an interior minimum when $\beta < L^C_D$. Thus, an equilibrium involving this sort of partial revelation cannot exist.

(b) In the second candidate for an equilibrium involving partial revelation, the prices and corresponding probabilities of sale must satisfy: $p^+_2 > p^-_2$ and $s(p^+_2) < s(p^-_2)$ (if the higher price also achieves at least as high a sales volume, then it will be mimicked). Since θ^m must be indifferent between the two prices, $s(p^+_2)[p^+_2 - (1 - \theta^m)L^C_D] + [1 - s(p^+_2)]\beta\theta^m - s(p^-_2)[p^-_2 - (1 - \theta^m)L^C_D] - [1 - s(p^-_2)]\beta\theta^m = 0$. However, this difference is decreasing in θ^m (since $s(p^+_2) < s(p^-_2)$ and $\beta < L^C_D$), so types in $(\theta^m, \theta^+]$ would prefer to defect from their putative equilibrium price of p^+_2 to p^-_2. Thus, an equilibrium involving this sort of partial revelation cannot exist. QED.

Continuation of Discussion of Pooling Equilibrium

Beliefs for the consumer now take the following form. If the firm (in a confidential regime) retains its technology, then consumers believe that $\theta_1 \in [\Theta, \bar{\theta}]$. Since the equilibrium involves complete pooling, the maximum price consumers are willing to pay is given by $V - (1 - \mu(\Theta))L^C_P$, where $\mu(\Theta)$ is the conditional mean of θ_1, given that $\theta_1 \in [\Theta, \bar{\theta}]$. That is, $\mu(\Theta) \equiv \int\theta_1 g(\theta_1)d\theta_1/(1 - G(\Theta))$, where the integration is over $\theta_1 \in [\Theta, \bar{\theta}]$. Notice that: (a) $\mu(\underline{\theta})$ is the unconditional mean (which we will continue to denote simply by μ); (b) $\mu(\Theta) > \Theta$ for all $\Theta < \bar{\theta}$; and (c) $\mu'(\Theta) > 0$. Moreover, Assumption 1 and the fact that $\beta < L^C_D$ imply that $V - (1 - \mu(\Theta))L^C_P - (1 - \theta_1)L^C_D > \beta\theta_1$ for all Θ and $\theta_1 \in [\Theta, \bar{\theta}]$. Thus, every type of firm prefers to sell a unit rather than to employ the technology in its alternative use. Hence, all types of firms will sell N units.

Firm profits in Period 2 following retention of the technology therefore become:

$$\Pi^C_2(r; \theta_1, \Theta) = N[V - (1 - \mu(\Theta))L^C_P - (1 - \theta_1)L^C_D].$$

These profits are clearly increasing in θ_1; that is, safer products are more profitable. Thus the form of consumers' beliefs is rationalized, and we can find the worst type of technology retained by equating these profits to the profits from replacing the technology, $\Pi^C_2(n) = N[V - (1 - \mu)L^C] - t$. Thus, the worst technology retained in a pooling equilibrium, denoted θ^{CP}, is given by:

$$N[V - (1 - \mu(\theta^{CP}))L^C_P - (1 - \theta^{CP})L^C_D = N[V - (1 - \mu)L^C] - t.$$

Recall that the worst technology retained in the revealing equilibrium satisfies $N[V - (1 - \theta^C)L^C_P - (1 - \theta^C)L^C_D] = N[V - (1 - \mu)L^C] - t$. Since $\mu(\theta^C) > \theta^C$, it follows that $N[V - (1 - \mu(\theta^C))L^C_P - (1 - \theta^C)L^C_D] > N[V - (1 - \mu)L^C] - t$. Thus, while the firm is indifferent about replacing the type θ^C technology in the revealing equilibrium, it strictly prefers to retain this technology in the pooling equilibrium. Therefore, the retention threshold when $\beta < L_D^C$ (i.e., in the pooling equilibrium) is yet lower than the retention threshold when $\beta > L_D^C$ (i.e., in the revealing equilibrium); that is, $\theta^{CP} < \theta^C$. *A fortiori*, $\theta^{CP} < \theta^O$.

The results stated in Propositions 1-3 apply equally to the comparison between confidential and open regimes when the confidential regime is characterized by a pooling equilibrium, with some minor differences. We briefly summarize these results below without their formal re-statements.

The replacement threshold for the technology is strictly lower in a confidential regime; that is, $\theta^{CP} < \theta^O$. This holds now even if $\lambda^C = \lambda^O$, because the less safe products can obtain the higher pooling price for their products. The firm makes lower R&D investments in a confidential regime, since it replaces the technology less often. The average quality of the technology always improves from Period 1 to Period 2 in both regimes, but it is higher in Period 2 in an open regime than in a confidential regime. The average safety of products sold in Period 2 is lower in a confidential regime than in an open regime (however, the average safety of products sold in a confidential regime cannot decline from Period 1 to Period 2); this is now a direct consequence of a lower average quality of technology, since there is no demand reduction in equilibrium.

Results analogous to those in Proposition 5 can be obtained. Note that now the maximum willingness to pay for openness is given by $M(\lambda^O) \equiv \Pi_1^O(\lambda^O) - \Pi_1^{CP}$, where:

$$\Pi_1^{CP} = \{N[V - (1 - \mu)L^C] - t\}(1 + G(\theta^{CP})) + \int N[V - (1 - \mu(\theta^{CP}))L_P^C - (1 - \theta_1)L_D^C]g(\theta_1)d\theta_1,$$

and where the domain of integration is $[\theta^{CP}, \bar{\theta}]$. It is straightforward to show that the functions Π_1^O and Π_1^{CP} are equal when $\lambda^O = \lambda^C$ *and they are evaluated at the same threshold value*. With a slight abuse of notation, we write this function as $\Pi_1^O(\lambda^C; \theta)$. Of course, when $\lambda^O = \lambda^C$, we have shown that the threshold values have the ranking $\theta^O = \theta^C > \theta^{CP}$. Thus, $M(\lambda^C) > (<) \ 0$ as $\Pi_1^O(\lambda^C; \theta^C) > (<) \ \Pi_1^O(\lambda^C; \theta^{CP}) = \Pi_1^{CP}$.

The function $\Pi_1^O(\lambda^C; \theta)$ is clearly increasing in θ for all $\theta < \theta^C$ (see below for details), which implies that $M(\lambda^C) > 0$. As before, this willingness to pay for a credible commitment to openness decreases as λ^O increases, but at a diminishing rate; this is the same result as in Proposition 4, which is illustrated in Figure 2.

<u>Properties of the function $\Pi_1^O(\lambda^C; \theta)$ for the Pooling Analysis</u>

This function is given by:

$$\Pi_1^O(\lambda^C; \theta) \equiv \{N[V - (1 - \mu)L^C] - t\}(1 - G(\theta)) + \int N[V - (1 - \theta_1))L_P^C - (1 - \theta_1)L_D^C]g(\theta_1)d\theta_1,$$

and where the domain of integration is $[\theta, \bar{\theta}]$. Differentiating and collecting terms implies:

$$\partial\Pi_1^O(\lambda^C; \theta)/\partial\theta = [(\mu - \theta)NL^C - t]g(\theta) = [(\theta^C - \theta)NL^C]g(\theta).$$

It is clear that $\partial\Pi_1^O(\lambda^C; \theta)/\partial\theta > 0$ for all $\theta < \theta^C$. Thus, $\Pi_1^O(\lambda^C; \theta^C) > \Pi_1^O(\lambda^C; \theta^{CP}) = \Pi_1^{CP}$ and hence $M(\lambda^C) > 0$. QED.

<u>Third-Party Harms and Pooling</u>

Recall that in the discussion of firm liability for third-party harms, we recognized that β

could be such that $\tilde{L}_D^i > \beta > L_D^i$. Thus, while a revealing equilibrium would exist without firm liability for third-party harms (since $\beta > L_D^i$), their inclusion in the liabilities faced by the firm might result in a level of losses for the firm such that $\tilde{L}_D^i > \beta$. Accounting for the dependence of θ^{CP} and θ^C on the level of losses, let us briefly employ the notation $\theta^{CP}(\bullet)$ and $\theta^C(\bullet)$. We know that $\theta^{CP}(\tilde{L}^C) > \theta^{CP}(L^C)$, and that $\theta^C(\tilde{L}^C) > \theta^C(L^C)$. Since $\theta^{CP}(\bullet) < \theta^C(\bullet)$, this means that it is possible that, should $\tilde{L}_D^i > \beta > L_D^i$, then $\theta^{CP}(\tilde{L}^C) < \theta^C(L^C)$. Thus, while third parties would now receive some compensation for their harms, the shift from a revealing equilibrium to a pooling equilibrium could mean that third parties (as well as consumers) might also suffer more accidents.

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